# The Modulation of the Diurnal Cycle of Rainfall by Convectively Coupled Equatorial Waves over the Maritime Continent

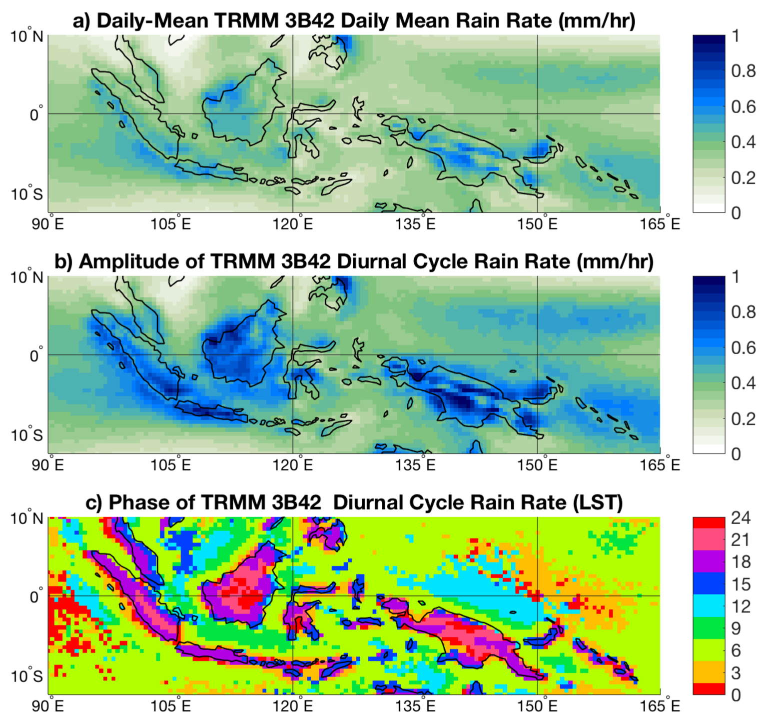

Naoko Sakaeda[1] (nsakaeda@ou.edu), George Kiladis[2], and Juliana Dias[2]

[1]School of Meteorology, University of Oklahoma, Norman, Oklahoma, USA

[2]Physical Sciences Division, NOAA/Earth System Research Laboratory, Boulder, Colorado, USA


## Background

Numerous studies have shown the diurnal cycle of tropical rainfall and cloudiness varies with the MJO over both land and ocean. However, it is less known how the convectively coupled equatorial waves (CCEW) interact with the diurnal cycle. The unique topography of the Maritime Continent results in geographical variability in the rainfall characteristics and the diurnal cycle, which are often difficult to be well-represented in numerical models. This study examines how the characteristics of the diurnal cycle of rainfall vary with the MJO and CCEWs over the Maritime Continent using TRMM and GPM data.

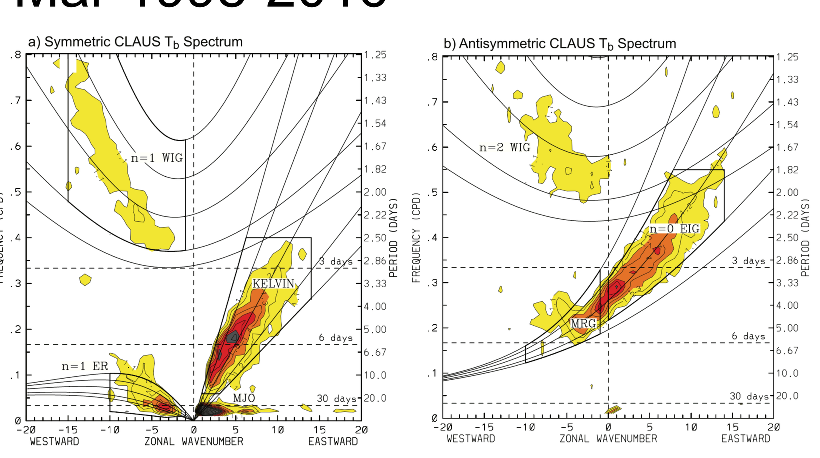


The examination of the interactions between the diurnal cycle and large-scale disturbances can also provide insights into the dynamical controls of the rainfall and cloudiness over this region.

Climatological daily mean rainfall, amplitude, and phase of the diurnal cycle during November-March using TRMM 3B42 rain rates.

## Data and Methodology

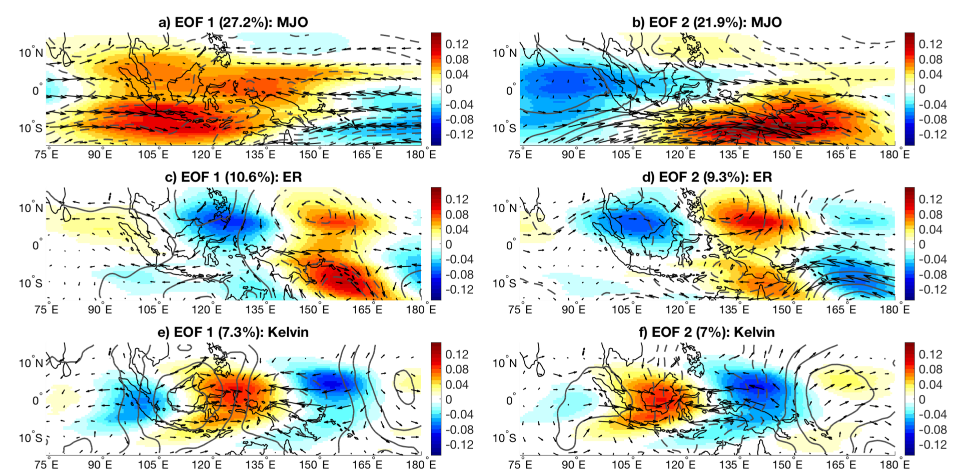
- TRMM 3B42: 3-hourly 0.5°x0.5° grids rain rates
- TRMM 2A25 Precipitation Radar (PR)/GPM Dual PR Ku-band: gridded to 3-hourly 0.5°x0.5° grids convective and stratiform rain rates
- ERA-Interim Reanalysis: 6-hourly 0.7°x0.7° grids
- Study period: Nov-Mar 1998-2016
- TRMM 3B42 rain rate filtered for CCEW and the MJO based on Wheeler and Kiladis (1999)



Figures from Kiladis et al. (2009), Rev. Geophys.

## Results

### Wave Structures:



•Structures of the leading EOFs show that filtered rain rates capture the known structures of the MJO and CCEWs.

FIG 1. Rain rate (shaded), 850-hPa geopotential height (contoured), and 850-hPa horizontal winds (vectors) associated with the first two leading EOFs of TRMM 3B42 rain rate that is filtered for the MJO (a-b), ER (c-d), and Kelvin (e-f) waves over the MC.

### Cross Spectral Analysis between Diurnal Amplitude and Wave-filtered OLR:

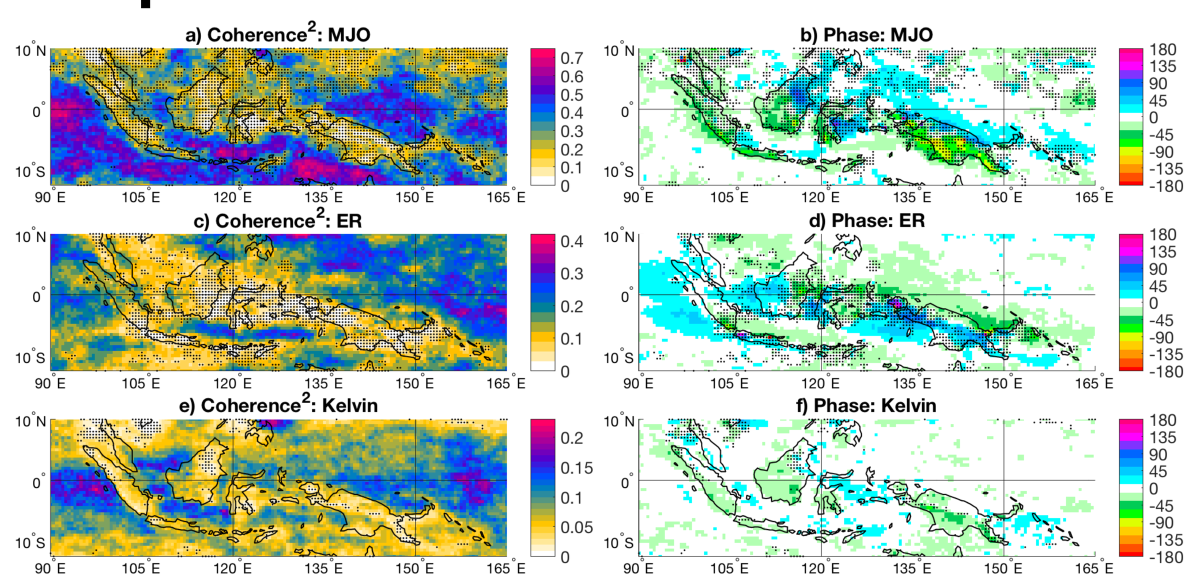


FIG 2. Point-by-point coherence[2] and phase relationship between daily wave-filtered TRMM 3B42 rain rate anomaly and the amplitude of TRMM 3B42 diurnal cycle based on cross spectral analysis. For phase, negative values indicate that the peak of diurnal amplitude leads the peak of wave-filtered rain.

• Phase indicates that the diurnal amplitude tends to lead the passage of MJO and Kelvin convective envelopes but lags the passage of ER convective envelopes. Kelvin waves have more systematic relationship with the diurnal cycle over the islands than the MJO or ER waves.

### Probability Distribution of Diurnal Amplitude & Phase:

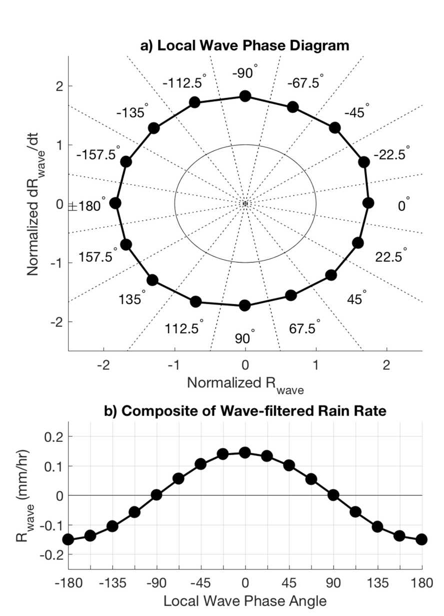


FIG 3. Local wave phase diagram using normalized wave-filtered rainfall and its tendency

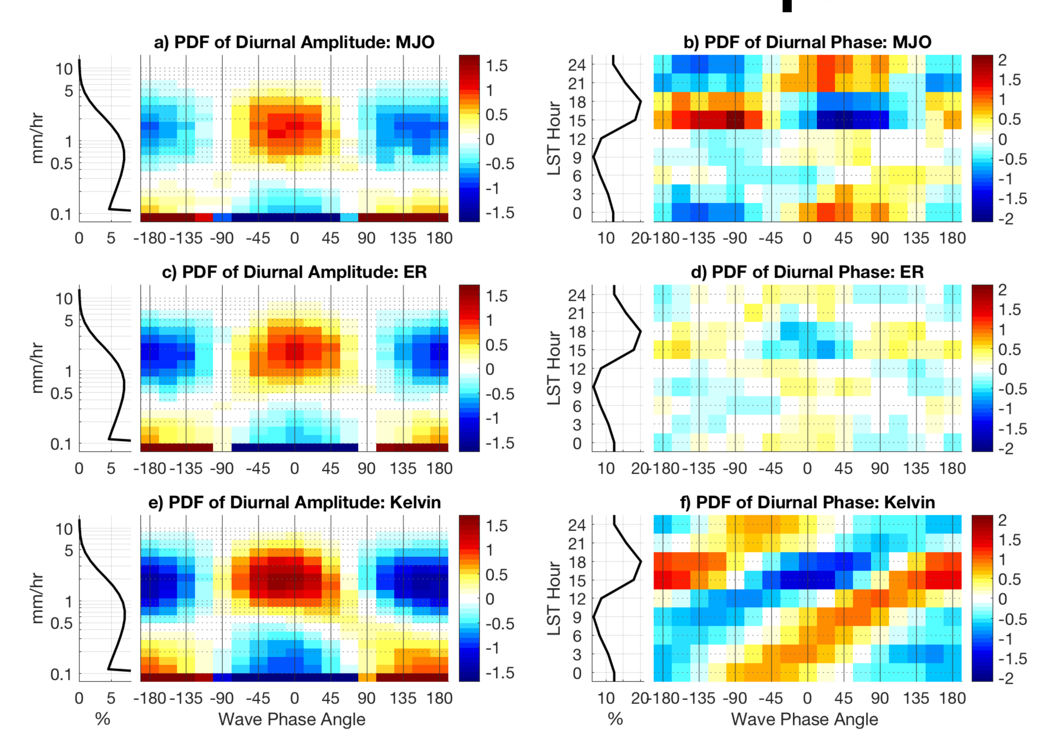


FIG 4. Climatological probability distribution function (PDF, black line) in % and anomalous PDF of diurnal amplitude and phase at each local wave phase angle over the MC islands.

• The rainfall data are composited based on the local phase of the wave's convective envelopes (Fig. 3)

• The peak in the amplitude of the diurnal cycle tends to be followed by the delay in the phase of the diurnal cycle for the MJO and Kelvin waves (Fig. 4).

## Convective vs. Stratiform Rain Rate Variability:

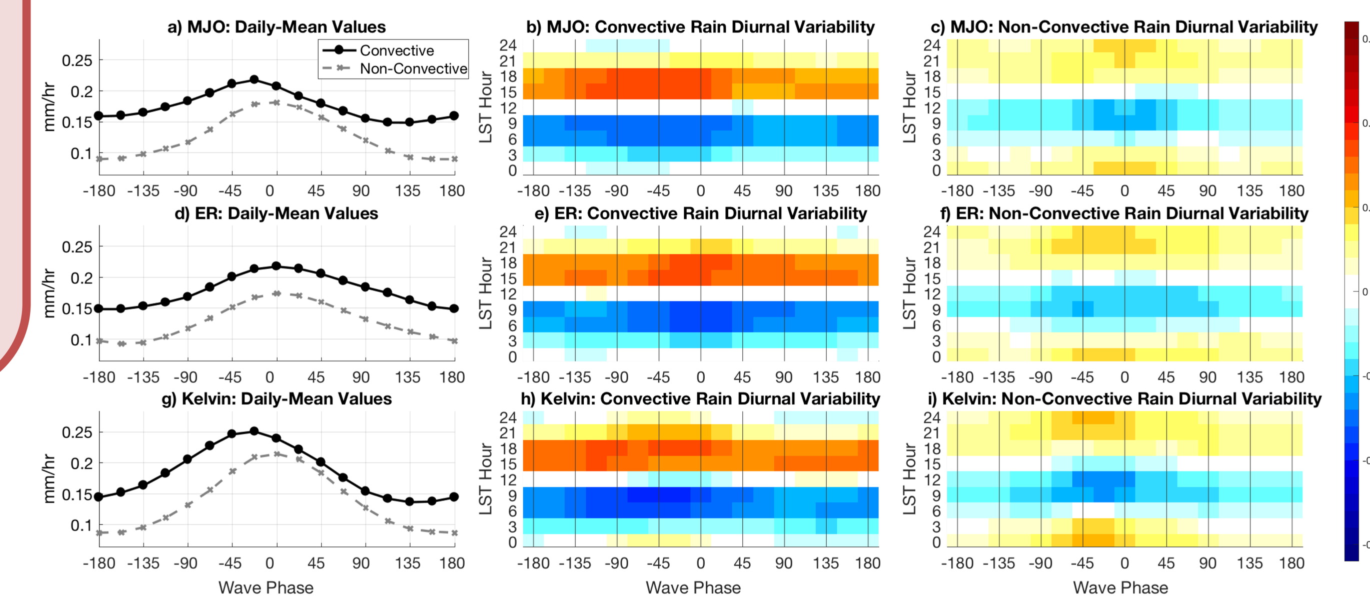


FIG 5. Composites of PR/DPR convective and non-convective rain rates based on the local phase angle of the wave convective envelopes over the MC islands. (Left column) Daily-mean and (middle-right columns) 3-hourly LST values show the anomalies from daily-mean at each local wave phase.

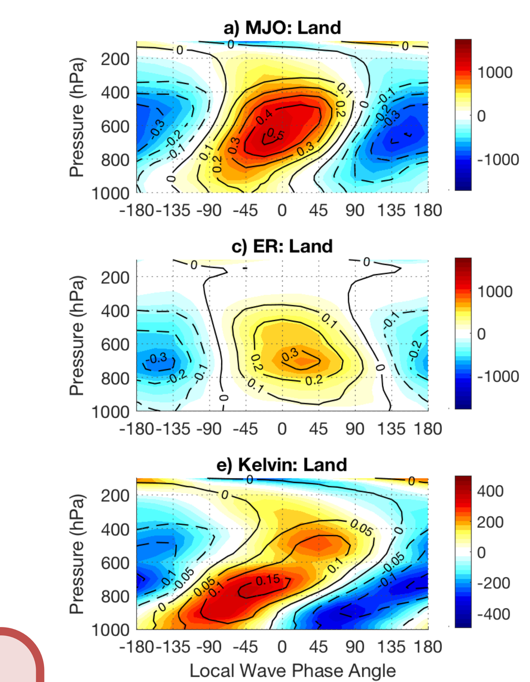
• Convective peak tends to lead stratiform peak within the MJO and Kelvin waves, but they peak simultaneously within the ER waves. (left column of Fig. 5)

• The amplitude of the diurnal cycle peaks with the convective peak, while the delay in the hour of peak diurnal rainfall is associated with stratiform rain.

• For the diurnal cycle, the convective peak (~15-18 LST) also leads stratiform peak (~21-24 LST). (right columns of Fig. 5)

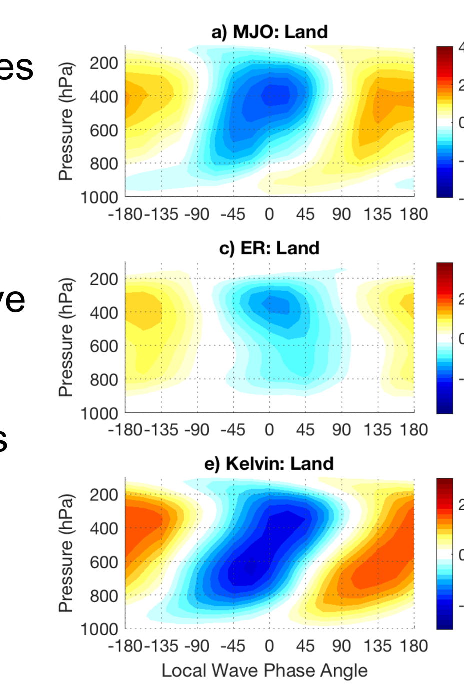
### Vertical Profiles of the Environment:

• The transition from convective to stratiform is associated with the gradual vertical build up of moisture and associated vertical motion, which appears most strongly within Kelvin wave.

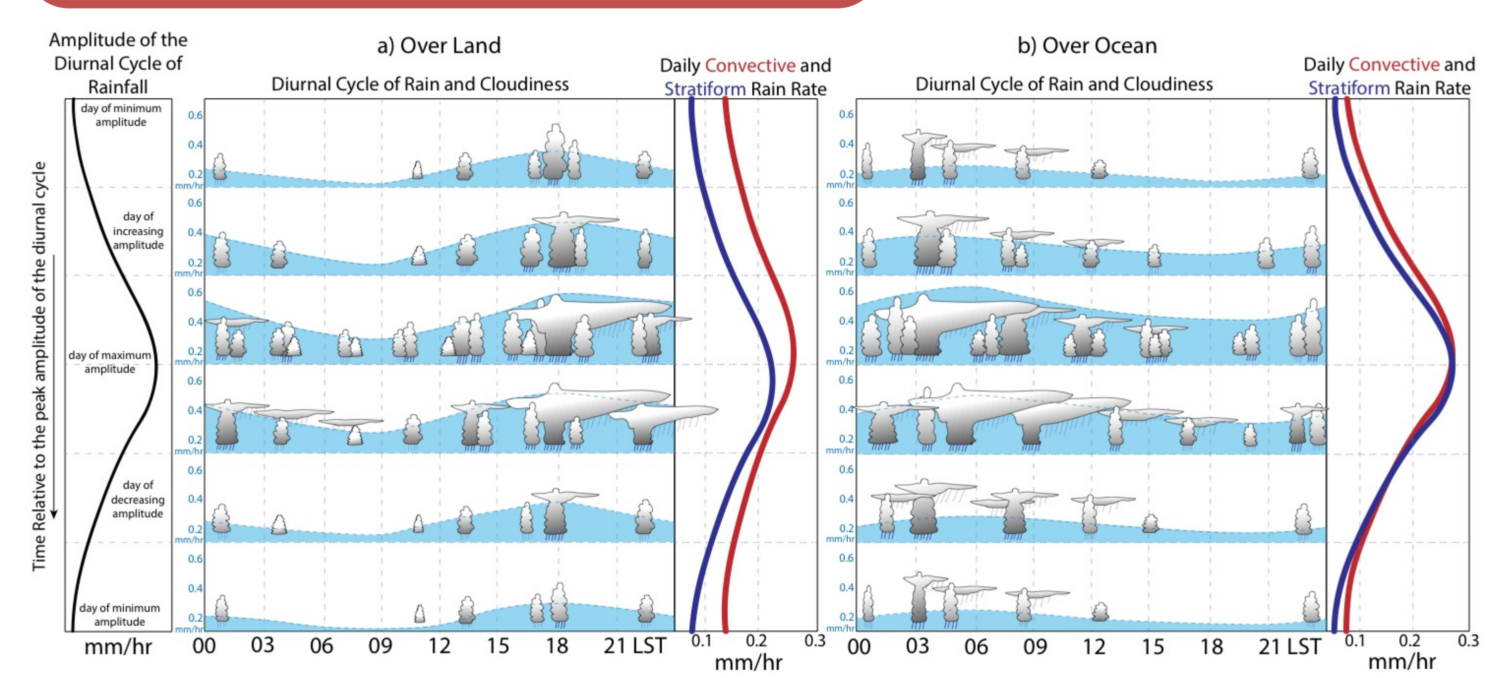


(Left) FIG 6: Composites of moist static energy (J/kg, shaded) and specific humidity (g/kg, contoured) anomalies based on the local wave phase over the MC islands.

(Right) FIG 7: Same as Fig. 6, except showing the composites of pressure velocity (hPa/s).



## Summary



(left) FIG 8: Schematic of the variability of the diurnal cycle in cloudiness and rainfall relative to the peak in the amplitude of the diurnal cycle within the enhanced convective envelopes of the MJO and CCEWs (a) over the MC islands and (b) surrounding ocean.

(bottom) FIG 9: Schematic of the evolution of rain type, amplitude of the diurnal cycle, tropospheric humidity, and clouds associated with the MJO, ER, and Kelvin waves. The WIG and EIG have similar variability to Kelvin wave.

• Over the MC islands, the peak in the amplitude of the diurnal cycle occurs at the timing of peak convective rainfall (Fig. 8a).

• Delay in the phase of the diurnal cycle occurs due to increased stratiform rain (Fig. 8a).

• The waves that generate steeper vertical tilt of moisture more effectively separate the peak timing of convective and stratiform rain, which results in stronger relationship between wave passage and the modulation of the diurnal cycle (Fig. 8).

• The surrounding ocean shows some similar results, but the convective and stratiform rain peak more simultaneously within the waves.